

Diode Pumped Laser

Christopher K. DeBolt
Naval Explosive Ordnance Disposal Technology Division (NAVEODTECHDIV)
Code 50A29

2008 Stump Neck Road
Indian Head, MD 20640-5070

phone: (301) 744-6850 x247 fax: (301) 744-6947 e-mail: debolt.eodtc@eodmgate.navsea.navy.mil
Award #: N0001498WX30024

Dr. Owen C. Hofer
SPARTA, Inc.

4901 Corporate Drive
Huntsville, AL 35805

phone: (205) 837-5282 x2600 fax: (205) 890-2041 e-mail: owen_hofer@huntsville.sparta.com

Dr. Robert G. Root
Prism Science Works
896 Beacon Street

Boston, MA 02215-3139

phone: (617) 437-6433 fax: (617) 437-6410 e-mail: prism@tiac.net

LONG-TERM GOALS

Explosive Ordnance Disposal (EOD) Technicians require the capability for long standoff disruption of Improved Conventional Munitions (ICMs), many of which contain Electronic Safe and Armed Fuzes (ESAFs), scatterable submunitions, and unexploded ordnance (UXO). Diode pumped lasers and the phenomenology of the laser beam interaction with ordnance items need to be studied, characterized, and developed for this application.

OBJECTIVES

Lamp pumped lasers are proven to have some merit for the long stand-off disruption of ordnance. However, the lamp pumped laser system is large and expensive, requiring a large armored vehicle platform. Diode pumped lasers have a beam quality figure of around 3 to 5 compared to a figure of approximately 130 for lamp pumped lasers. The output aperture diameter can be reduced to approximately 1/3 the diameter of the lamp pumped output aperture (from 40 cm to 15 cm). Also, diode pumped lasers are electrically more efficient, allowing the prime mover, waste heat, and power subsystems to be greatly reduced in size. System maintenance costs will be vastly diminished due to the inherent ruggedness of the diode laser. But the diode pumped laser beam has a much greater brightness, and the effects of spot size and this higher irradiance on ordnance failure modes must be determined.

There are three major technical issues associated with the development of a diode pumped laser for ordnance disruption which will be addressed: (1) Does a diode pumped laser meet all of the surface

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mine, submunition, and UXO clearance mission requirements of engagement range, system effectiveness, system weight, system volume, and irradiation time?; (2) What is the basic laser/munition interaction phenomenology and the failure modes of those munitions?; and (3) What are the diode pumped laser's operational characteristics, such as diode lifetime and optimum coolant temperature?

The objectives of this program will be to demonstrate, with both laboratory and field-testing, the feasibility of diode pumped lasers for UXO and submunitions neutralization. Documentation of these tests will demonstrate the operational characteristics of diode pumped laser hardware. A diode pumped laser head and power supply have been purchased, delivered, and demonstrated in the laboratory. They will be integrated with the beam control, prime power, waste heat, and fire control subsystems for performance on a field test bed.

APPROACH

Models for the laser phenomenology will be applied and laboratory testing will be performed to validate those models. Phenomenology issues to be tested by Dr. Robert Root of Prism Science Works include: effects of spot size irradiance, and waveform on target heating (absorptance); validity of the thermal response model near threshold (low power or thick casing); ablation characteristics of plastic munitions; and melt removal mechanisms at high irradiance. Parameters of the laser will be adjusted accordingly and applied during subsequent tests conducted by Dr. Owen Hofer of SPARTA, Inc.

The advantages of diode pumped lasers over arc lamp pumped devices will be demonstrated, first in the laboratory, and then in the field. These advantages include increased engagement range, improved electrical efficiency, more compact packaging, and reduced overall system cost and complexity.

WORK COMPLETED

Prism Science Works has completed the first phase of laser phenomenology testing and has refined the models developed. In most cases there was close correlation between the models and the test results.

SPARTA, Inc. and Prism Science Works performed laboratory testing of characterizing the repetitive pulsed diode pumped laser beam, including power and spot diameter measurements, using Prism's portable diagnostics suite. These tests provided the first data on the effect of the repetitively pulsed waveform on the phenomenology and also provided essential information of the beam characteristics. The modeling and analysis of the earlier CW laser test data was refined to include the energy losses to the target holder and a qualitative model of paint removal. In most cases there was close correlation between the models and the test results.

The nominal 500-watt laser produced 440 watts on target at 50 meters range with a spot diameter of 2.2 to 3.3 mm; the latter value translates to a beam quality (M2) of approximately 3. This means that the system will produce a spatial flux density on target at 50 meters of approximately 3,890 watts/cm² for a 500 watt laser; a value twice that for the 1,000 watt system. Design and development has also been completed on the laser power subsystem and waste heat subsystem. System integration of all hardware is currently occurring in preparation for the December 1998 live field tests at Redstone Arsenal.

Figure 1 shows the peak flux density at various ranges for a diode pumped laser at different power levels vs. the lamp pumped laser for the Mobile Ordnance Disrupter System (MODS).

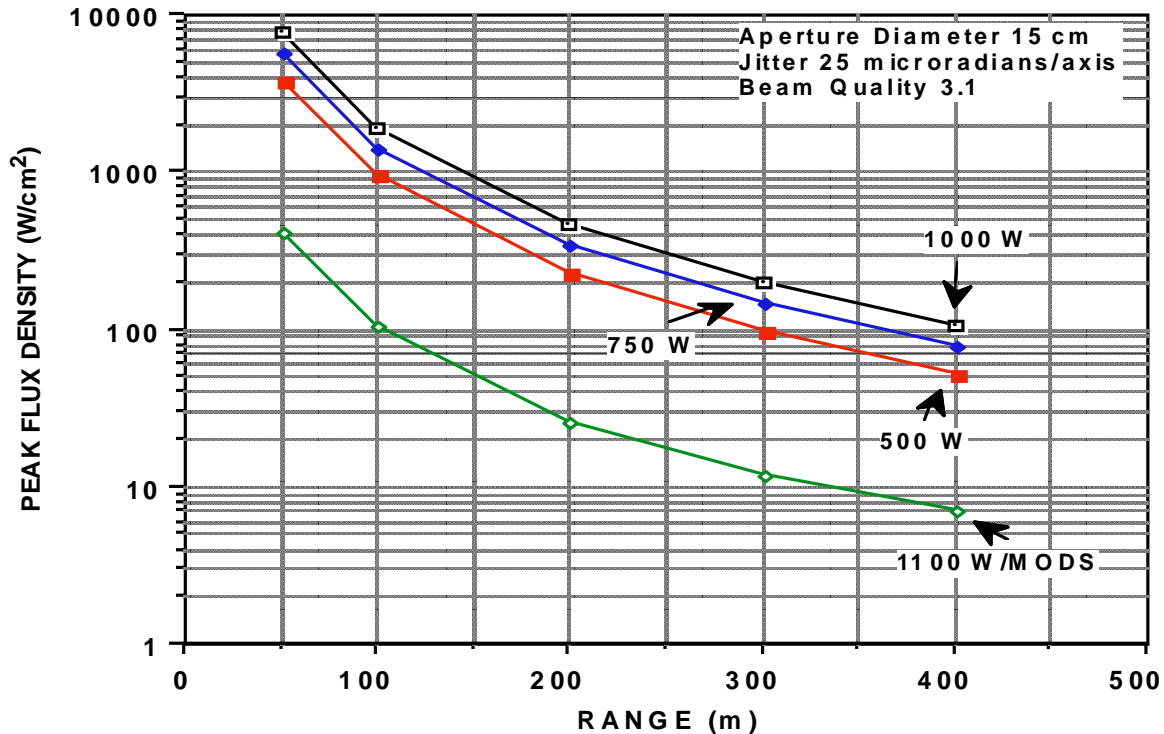


Figure 1. Laser Comparisons

RESULTS

Initial phenomenology testing revealed if the irradiance (power density) is too high on thicker metal targets, the absorptance drops significantly after a short time. It was concluded that the front surface transitioned from the oxidation phase (where high absorptance is obtained because very little of the laser energy is reflected) through clean-up to the melt region (where absorptance is low because the oxidation is now cleaned off and the laser energy is largely reflected) before the heat is conducted to the rear surface of the target wall and the explosive filler. The result is a longer time to reach the critical temperature at the explosive than if the irradiance were lower. Thus, there is an optimum combination of power and spot size (irradiance or power density) for target munitions. This is especially important on thicker metal cased munitions.

The laser device is operating under conditions close to the predicted performance. The annular beam in the near field is larger than expected and coupling it into the telescope at the position most convenient has forced modification to the telescope. The annular near field beam makes the system extremely difficult to characterize. Only far field beam power and spot diameters will be useful performance measurements.

The most recent phenomenology tests using the SPARTA, Inc. repetitively pulsed laser revealed that the “real” beam has a great deal of structure at the 50 m location and the irradiance pattern “danced” around during each run. Video coverage confirmed that the interaction with painted targets proceeds by first removing the paint, then heating the exposed metal surface. This mechanism is common for

short pulse (few μs) interactions, particularly at long wavelengths (10.6 μm), but had not been confirmed for these relatively long pulse, high duty cycle engagements at 1.06 μm . The video also revealed that the motion of the beam was slow enough that a number of pulses sufficient to cause surface damage (melting) could fall on the same location before the beam moved to another location. The complex beam motion has precluded detailed analysis of the data, but preliminary results suggest that the repetitively pulsed laser couples less efficiently than the CW laser. The decrease in effective absorptance is relatively small and should not prevent the repetitively pulsed laser from performing well in munition neutralization tasks.

IMPACT/APPLICATIONS

A laser ordnance neutralization system that is compact and electrically efficient, with reduced waste heat dissipation requirements, will permit the system to be mounted on an inexpensive common platform, such as a High Mobility Multi-purpose Wheeled Vehicle (HMMWV). The greatly improved beam quality facilitates putting more power on target, thus extending engagement ranges and shortened engagement times. The combination of these factors, plus increased ruggedness and reduced maintenance requirements, portends an affordable and versatile system for fast and safe long stand-off disruption of large concentrations of surface mines, scatterable submunitions, and UXO.

TRANSITIONS

Technology developed during this program will be transitioning to demonstration and validation (6.3) beginning in FY99. Proposals to the Explosive Ordnance Disposal/Low Intensity Conflict (EOD/LIC) and the Environmental Security Technology Certification Program (ESTCP) offices were well received, and have been recommended for funding. The technology will be used in situations of high target density by EOD detachments, combat engineers, and range clearance personnel. The result of these 6.3 projects will lead to an advanced development (6.4 acquisition) effort in FY 01, starting with an Analysis of Alternatives which should start in FY00. This effort is already envisioned, and is referred to as the HMMWV Laser Ordnance Neutralization System (HLONS).

RELATED PROJECTS

This program is an outgrowth of the requirement for the MODS, which is capable of long stand-off disruption of munitions, but is large, expensive, difficult to maintain, and limited in engagement range. The MODS prototype is currently being used for limited range clearance at Nellis AFB, and the concept of using laser energy for standoff neutralization has been well received, acknowledging the limitations of the MODS. The current diode pumped laser technology development builds on the technology developed during the Precision Laser Machining program begun in 1994 under the Defense Advanced Research Project Agency's Technology Reinvestment Program.

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